gradually introduced efficiencies into the traditional loop architecture, such as digital loop carrier ("DLC") systems at the remote terminal that used multiplexers and other electronics and the addition of high-capacity feeder plant, in order to enhance the transmission functionality of the loop to better accommodate voice service. Even with significant gains in technology that greatly improved the efficiencies for transmitting voice service, however, the traditional ILEC loop architecture could only support transmission rates of 56 kpbs (nominally) in best-case configurations.

12. As consumer demand for bandwidth-rich data services grows, the inherent constraints in the ILECs' traditional loop architecture have caused the ILECs to explore and implement a "next generation" architecture that better utilizes the full transmission functionality of both the low and high frequencies of the local loop in order to provide a wider range of telecommunications services to a broader cross-section of end-users. In particular, I discuss how the ILECs have enhanced their loops by incorporating a much greater use of fiber, introducing splitting and additional multiplexing functions at remote terminals and additional demultiplexing functions at the central office and elsewhere. These loop enhancements have made it possible to greatly increase and improve the transmission functionality of the loop. Indeed, the introduction of next-generation architecture permits ILECs and their data affiliates to provide a whole host of new services, and higher-quality existing services, to their customers while also increasing the ILECs' own economies in their loop plant.

13. I also explain that the transmission functionality provided in next generation RT architecture is no different than that the transmission functionality delivered in a more traditional DLC architecture. Indeed, none of the adjustments that the ILECs are making alter the basic

characteristics of the unbundled loop element that the Commission has recognized and incorporated into its current unbundling rules. First, the loop still remains the essential pathway between the subscriber's premises and the central office. Second, the loop configuration for next generation architecture is no different: a copper pair from a customer's premises to a remote terminal; fiber from the RT to the central office; and electronics to manage the efficient use of the transmission media. Third, the function of the loop between the customer's premise and the central office remains straightforward and unchanged: it is the transmission functionality necessary for retail customers to send and receive information between their locations and the network of the service provider.

14. Next, I describe how the loop transmission functionality in next generation RT architecture encompasses the entire loop, including: a) a copper pair from a customer's premises to a remote terminal; 2) fiber from the RT to the central office; and 3) all attached electronics necessary to manage the efficient use of the transmission media, including, but not limited to: line cards, DSLAMs, and other remote terminal electronics, ILEC-owned line splitters, and the statistical multiplexing functionality of ATMs.

15. Finally, because next generation RT architecture is being deployed closer to customers, I explain the reasons why continuation of CLECs' right to access the entire loop is the only viable option that will enable CLECs to compete in the mass-market. In particular, I explain why, in a next-generation RT architecture, remote terminal collocation and spare copper solutions are insufficient to support a competitive marketplace. For example, space constraints, severe diseconomies of scale and other limitations lead to the inevitable conclusion that, at its

best, remote terminal collocation will be used only in isolated circumstances, and will never be able to support mass-market competition. I also explain that spare copper facilities that extend between the central office and the customer's premises are not substitutes for CLEC access to the full capabilities made possible by the use of shorter copper runs, signal splitting at the RT and the multiplexing of voice and data bit streams onto fiber from RTs to an ILEC central office, all of which are part of the new loop architecture.

16. Accordingly, I recommend that the Commission categorize DSLAMs, especially those in remote terminals, as part of the electronics used to support the loop element, and to otherwise retain its current rules that entitle CLECs to obtain access to all "attached electronics" used to support the basic functionality of the loop.

III. A TECHNICAL LOOK AT TRADITIONAL AND NEXT-GENERATION-ILEC LOOP ARCHITECTURE.

A. Traditional ILEC Loop Architecture Was Designed to Accommodate Analog Voice Service and Is Ill Equipped to Meet Consumer Demand for High-Bandwidth Services.

17. The ILECs' traditional loop architecture was designed to handle voice communications, and it principally employed analog technology that uses a pair of "dumb" copper wires connecting the customer to the central office. At the central office, ILECs connect the copper and add functionality in the form of circuit switches, test capabilities, new switching software, and out-of-band network signaling. The loop occasionally used pair gain or channelization technologies that employ devices at the customer premises and corresponding devices at the central office. Both pair gain and channelization enhance the transmission functionality of the loop through use of multiplexing technology.[1]

[1] Both single-channel and multi-channel systems were usually used in congested areas to defer the need for new telephone cable installations. The single-channel systems provide an

18. Until around 1960, interoffice facilities were typically analog copper in nature. At that point in time, digital technology was first introduced into the interoffice plant. While still a copper based technology, it took advantage of pulse code modulation techniques, otherwise known as "T-1," to digitize the signal and to place multiple signals onto a single facility. The construction of interoffice copper cable plant is costly because it is extremely labor intensive and requires support structure (*i.e.*, poles, conduits) for its entire routing, which is relatively lengthy as compared to subscriber plant. For this reason, engineering economics heavily favored the use of electronics and multiplexing in lieu of a total copper solution in the interoffice network.

19. In the 1970s, optical transmission technologies were introduced into the interoffice plant to enhance transmission functionality, improve the quality and reliability of the network, and reduce network costs. Today, interoffice plant consists almost entirely of fiber optics.

20. In many respects, the ILECs' outside service plant -- the facilities between the central office and the customer -- is no different from their interoffice facilities. Indeed, the same efficiencies that have been, and continue to be, introduced into interoffice facilities are also being deployed in outside service plant, although at a different pace. Originally, outside service

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additional channel by using a frequency spectrum above the voiceband. The frequencies commonly used were 28 kHz toward the station and 76 kHz toward the office. The multi-channel systems were used in low growth areas, typically on long loops. They furnish four to eight channels on a single cable pair. Unlike the single-channel systems, they do not attempt to use the physical cable pair as a voiceband path. Rather, they provide a concentrated remote terminal where customer connections are made, or a distributed remote terminal arrangement where customer connections are made in several locations along the same system. They generally operate with double wideband AM signals, using transmitted carriers at 8 Khz intervals in a band from 12 to 156 kHz. The carrier terminal and intermediate repeaters and the telephone are all powered by direct current sent over the carrier pair. *See* Declaration of Thomas Hill and Robert Frontera ("Hill/Frontera Decl.") for a discussion of multiplexing functionality.

plant consisted largely of copper pairs. In the 1970s, however, the traditional loop architecture was supplemented by the introduction of digital loop carrier "DLC" equipment in the ILECs' outside plant. DLC systems digitally encode and multiplex the traffic from subscribers' loops into DS1 (or higher) level signals[2] to provide more efficient transmission over the feeder facility or to extend the range traditionally permitted by copper loops that employ analog signals.[3] When DLC is used, analog signals are carried from customer premises to a remote terminal ("RT") where they are: (1) converted to digital signals; (2) multiplexed with other signals; (3) often converted from electrical to optical signals; and (4) carried over high-capacity feeder facility (generally fiber) to the ILEC central office. At the central office, a reverse process takes place in some or all of the aforementioned stages. The most common form of multiplexing for voice traffic in a DLC arrangement is time division multiplexing ("TDM"), which assigns a particular time slot, or position in a cycle, of fixed information capacity (64 kilobits) to create the communications path within a single physical facility.[4]

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[2] DS1 channels carry 1.544 megabits per second ("Mbps") of data, the digital equivalent of twenty-four 64 kbps analog voice channels.

[3] The two traditional DLC systems are universal DLC ("UDLC") and integrated DLC ("IDLC"). UDLC, the older of the two systems, is not directly integrated with the switch. Thus, the ILEC's central office equipment (i) converts optical to electrical signals in fiber driven systems and (ii) converts digital signals back to analog before the signals are delivered to the main distribution frame. IDLC is integrated with the switch at the DS1 level and provides a direct, digital interface to a digital central office switch. As the Commission is aware, the procedure to unbundle IDLC is different, because, unlike UDLC traffic, IDLC traffic is not demultiplexed and converted back from digital to analog before it reaches the central office switch. Exhibit A, attached to this declaration, illustrates an ILEC's loop architecture supplemented by UDLC and IDLC.

[4] TDM is a technique for transmitting data, voice and/or video signals simultaneously over one communications medium by quickly interleaving a piece of each signal, one after another, in a fixed time sequence. TDM "samples" each voice conversation, interleaves the result of each sample with the results of sampling other conversations, and sends them on their way in a structured sequence. At the other end of the loop, the individual signals are "demultiplexed," which means they are reconstructed using a similar process in reverse

21. In a DLC arrangement, the loop from the subscriber's premises begins as a copper distribution pair and runs to the field side of the ILEC's Serving Area Interface ("SAI", which is sometimes referred to as a Feeder Distribution Interface or "FDI"), where it is connected to a copper feeder pair on the central office side of the SAI.[5] The copper feeder pair is then delivered to a remote terminal, which may be a controlled environmental vault ("CEV"), a hut, or a cabinet. A general description of each type of remote terminal is attached to my declaration as Exhibit B.

22. The copper feeder pair from the SAI is then hardwired to the DLC system within the remote terminal. The DLC equipment converts the analog signals on the copper from the subscribers' premises to digital format. The individual subscriber signals are then interleaved (multiplexed) into high speed signals and then, in most instances, converted from electrical to optical signals. This enables the signals to be transmitted to the central office, often over fiber facilities.[6] The DLC equipment typically includes a common control assembly ("CCA"),[7] which

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order. Each communication is placed on a time slot (or position in a cycle) of fixed duration and fixed position on the loop facility. The time duration of the slot limits both voice and data transmissions to 64 kbps. The multiplexer and demultiplexer at the remote terminal and central office both need to ensure that the particular time slot (or position in a cycle) corresponds to the appropriate customer.

5 The SAI is the interface point between the ILEC's distribution and feeder cable. Feeder cables terminate on a SAI in each serving area, where they are cross-connected to copper distribution cables. A single remote terminal may support several SAIs.

6 DLC systems employing copper feeder and T1 technology still use an electrical signal.

7 The Common Control Assembly ("CCA") typically contains equipment groups necessary to provision the DLC system, such as the common optics, common electronics and common support features. The common optics equipment group may include optical tranceivers that provide the optical-to-electrical conversion as well as the interface to the common electronics. The common electronics equipment group includes SONET formatters and Time Slot Interchangers ("TSIs"), which interface with the Channel Bank Assemblies ("CBAs"). System protection switching is also contained in the common electronics equipment group.

provides the capabilities needed to operate the entire DLC system, and channel bank assemblies ("CBAs"),[8] which provide the interface between the end user cable pairs and the DLC equipment.

23. The ILEC loop plant, regardless of architecture, can accommodate low-speed data transmissions. Even with significant gains in modem technology, however, the ILECs' traditional loop plant, absent improvement in the transmission equipment deployed, can only support data rates of 56 kpbs (nominally) in best-case configurations. Advances in design and large-scale integrated circuits have simultaneously increased speed and reduced modem cost. Modems built to the V.90 standard are intended to take advantage of the fact that -- except for analog subscriber lines to end users -- telephone networks already incorporate digital technology. As a consequence, analog transmission facilities are usually encountered in the link from the end user to the central office and, therefore, only one analog to digital Codec (A/D conversion) should be necessary. Thus, in the most favorable situation, performance-limiting impacts of spurious electrical signals (or noise) would only be encountered in the upstream path (from the user to the central office) due to the necessary A/D conversion. The effect would limit the upstream to V.34 speeds or 33.6 kbps in the ideal case and 56 kbps in the downstream direction (since the signal ideally would be digital from the ISP all the way to the end user modem).

The common support group includes alarms, common power supply, and maintenance and testing features.

8 The CBAs house various channel units assigned to individual customers, as well as common electronics used by all customers served by the CBA. Typically, the CBA can be wired to accommodate both low- and high-frequency spectrum traffic. The common CBA units derive the correct power options to be supplied to the CBA plugs as well as the interface to the CCA TSI units. Ringing generator units, metallic test access units and communications interface units may also comprise the CBA common units.

Given the varied conditions and loop lengths that exist in the plant, the aforementioned speeds are optimistic.

24. The explosive growth of the Internet, e-commerce, telecommuting, and ready access to information and entertainment has resulted in a dramatic increase in the number of customers that desire high-speed data service. As a result, in the past few years, consumer demand for high-speed Internet access capabilities has increased exponentially. In particular, demand for increasingly rich graphics, streaming audio, and now even streaming video applications are continuing to make consumers expect more and more bandwidth.

25. The introduction of xDSL technology has significantly increased the copper loop's ability to carry data transmission.[9] xDSL technologies are transmission technologies used on circuits that run between a customer's premises and the central office. xDSL technologies increase the ability of the standard twisted pair to carry high capacity data transmission by expanding the usable bandwidth of the copper line. Traditionally, xDSL technologies have been deployed on loops that are copper end-to-end from the central office to the customer premises ("home-run copper").

26. The ILECs' traditional architecture is ill equipped to address more remotely located consumers' demand for increased bandwidth. For example, noise and other signal impairments constrain data bit rates on longer loops. Because performance of xDSL technologies are affected by the electrical characteristics of the loop (including length), some loops cannot use xDSL technologies at all; others are constrained to rates that are still below

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[9] "DSL" is the acronym for Digital Subscriber Line. "x" is a variable, meant to encompass the various types of Digital Subscriber Line technologies and is used when referring generally to DSL.

what is needed to take full advantage of the possibilities of the Internet. As noted below, however, with the deployment of transmission equipment outside the central office by incumbent LECs, some types of DSL may be feasible on hybrid loops that are copper from the customer's premises to an intermediate equipment location -- the RT -- where signals are processed, multiplexed and transmitted over fiber optics from the RT to the central office.

B. The ILECs Have Responded to Consumer Demand for Bandwidth-Rich Data Services Through the Deployment of Next-Generation Architecture, Which Greatly Enhances the Transmission Functionality and Economics of the Local Loop Plant.

27. The inherent transmission constraints in copper conductors caused ILECs to look for ways to better utilize the full transmission functionality of their local loops so that they could meet consumer demand for bandwidth-rich services without replacing the entirety of their loop plant. In response, the telecommunications equipment manufacturers have made great advances in digital signal processing, opto-electronics, large-scale and very large-scale integration, environmental hardening, and power supplies.

28. Thus, consumer demand, coupled with the miniaturization of electronics, increased equipment capabilities and the growing environmental "hardness" of electronics used in such equipment -- along with the rapidly declining costs of such equipment -- has resulted in accelerated deployment of fiber in the ILECs' outside plant and electronics in remote terminals.[10] SBC has announced ambitious plans to deploy an overlay fiber/remote terminal electronic network to reach some 80% of end users in its service area within 3 years.[11] Similarly, other

[10] *See generally* Public Forum: Competitive Access to Next Generation Remote Terminals, CC Docket 96-98 et al. (May 10, 2000) ("NGRT Public Forum").

[11] *SBC to Offer DSL Through Neighborhood Gateways*, SBC Press Release (September 8, 2000) <http://www.sbc.com/News_Center/Article.html?querry_type=article&query =2000908-01>; Dick Kelsey, *FCC Approves SBC Neighborhood Gateway Plan*, Newsbytes (September 8, 2000) <http://www.newsbytes.com>.

major ILECs have publicly acknowledged more general plans for wide-scale deployment of this technology to provision broadband services.[12]

29. As a result, outside plant is rapidly employing digital end-to-end and the digital signals are more frequently carried some or all the way in an optical format. All this means higher and higher transmission rates from the customer premise to the network (where all service functionality resides) are becoming feasible.

30. These developments have enabled ILECs to implement a loop architecture that generally has the following characteristics:

- Much shorter runs of copper between the customer's premises and the first point at which customer communications are enhanced by transmission electronics;
- Electronics (and opto-electronic conversion) at the RT, where analog voice signals from the customer's premises are converted to digital;
- Splitting customer data and voice streams and application of multiplexing strategies best meeting the demands of the particular communications;[13]
- Fiber between the RT and ILEC central office (or other ILEC location) possessing very high transmission capacities; and
- Electronics at the ILEC central office end of the loop to demultiplex the aggregated traffic, so that voice traffic may be delivered to circuit switches and data traffic may be delivered to diverse carriers and Internet service providers ("ISPs").

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[12] *Industry Debates Access to ILEC 'Remote Terminals,'* Communications Daily (May 11, 2000); *Verizon Deploys Fiber Optics, Electronics, Bringing Additional Advanced Technology Services to Washington County*, Verizon Press Release (July 19, 2000) <http://newscenter.verizon.com/proactive/newsroom/release.vtml?id=40908>.

[13] ILECs frequently also place TDM signals (voice) on one fiber and ATM signals (data) on a separate fiber. ATM and TDM signal can co-exist on the same fibers simultaneously in several ways. It is technically feasible to carry TDM time slots within an ATM format. Another technically feasible scheme would involve wave division multiplexing (WDM) wherein each type of signal travels on the same fiber(s) at different wavelengths, e.g. TDM @ 1550 nm and ATM @ 1310 nm.

31. Exhibit C to this declaration illustrates an ILEC's typical implementation of such a loop architecture. Like the DLC systems described above, the copper distribution pair[14] running from the customer's premises is typically connected to the fiber feeder portion of the loop at, or near, the remote terminal.[15] However, in a forward-looking configuration with DSL-compatible DLCs, the copper segment of the loop is typically connected to a plug-in card ("line card") with integrated DSLAM/splitter functionalities. The line card plugs into one of the channel banks in the DLC equipment in the ILEC's remote terminal. The line card is the point at which the voice and data signals are separated and separately multiplexed onto one or more fiber feeder facilities, which transmit the signals back to an ILEC central office on separate pathways.

32. These transmission electronics introduced into the RT permit customer information to be handled based upon the differing characteristics and needs of voice and data traffic. For example, voice traffic is low density (*i.e.*, sends a relatively small amount of information) but extremely intolerant of latency (*i.e.*, delay). In contrast, data traffic often has high information density for short periods of time but can be somewhat tolerant of latency. Thus, the most efficient handling of voice streams and data streams may require that each be multiplexed differently. As noted above, the most efficient type of multiplexing for voice traffic

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[14] The Distribution Plant fed by DLC is designed in accordance with Carrier Serving Area (CSA) guidelines. Briefly, CSA guidelines state that the copper distribution cable shall be non-loaded (free of load coils) and distance limited (e.g. < 9 kft of 26 gauge copper, <12 kft of 19, 22, or 24 gauge copper). Moreover, the distribution cable shall not contain more than 2,500 feet of bridged tap in total, and no single bridged tap may exceed 2,000 feet. Thus, all end users served from a remote terminal via DLC should have loops free of impediments to digital transmission and the longest loop will not exceed 12 kft (or 9 kft in the case of 26 gauge copper).

[15] As noted above, DLC systems have, for some years, applied digitization to voice waveforms in the loop.

in traditional networks is generally TDM. In contrast, it is frequently more efficient to use statistical multiplexing for data traffic.[16]

33. At this point, fiber feeder is introduced into the loop, running from the remote terminal to an ILEC central office that carriers separate signal streams for aggregated voice and data traffic.[17] In the remote terminal, the splitter directs the voice stream to the fiber feeder facilities that will ultimately connect to a circuit switch in the central office; similarly, it directs the data stream to an ATM-like device at the central office. The bitstream carrying data traffic can be also combined with other data and voice traffic in the ILEC's SONET equipment at the remote terminal and carried on the same fiber(s).[18] Fiber feeder facilities run between the SONET equipment at the remote terminal and SONET equipment at the ILEC's serving central office.

34. Fiber feeder cable is generally an inch in diameter, regardless of the number of strands. Through the use of innerducts, the ILEC can place up to four fiber cables in the same conduit by partitioning the larger conduit into several smaller diameter conduits.[19] The conduit

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[16] Statistical multiplexing differs from TDM in that the share of the available bandwidth allocated to a given user varies dynamically. Statistical multiplexers fill available bandwidth based on the priority of the services awaiting transmission. If there is no contention for the facility at a particular point in time, a low priority communication will be sent, even though the end user has not "reserved" all of that capacity.

[17] If a single fiber facility is used, both types of traffic are brought to the customer's serving central office. If two facilities are used, the voice traffic is brought back to the customer's serving central office and the data traffic may be brought to a different location, depending on the ILEC's network design.

[18] There is no inherent technical reason why the ILECs need to separate the voice and data traffic over the same fiber. *See supra* n.13.

[19] In contrast, a copper cable occupies the entire conduit duct and provides only 1100 pairs if 22 gauge, 1800 pairs if 24 gauge, and up to 3,600 pairs if 26 gauge. In addition, copper cables are much heavier and much more labor intensive. For example, a 22 gauge copper cable pair

(which has a diameter of 3.5" to 4.0") is run underground to the ILECs' central offices. In an urban environment, the fiber is usually underground for thousands of feet before it enters a central office. In a suburban neighborhood, the fiber is typically underground for approximately 1,000 feet. In a rural area, the fiber may be underground for only a very short distance.

35. At the central-office, the ILEC introduces electronics that are required to demultiplex the separately aggregated voice and data traffic, so that voice traffic can be directed to circuit switches and data traffic can be directed to carry data switches that, in turn, route the communication to diverse end points. At the central office, the ILEC introduces electronics that terminate the feeder facility and 1) connects the TDM signal to the local digital circuit switch; 2) connects the ATM signal to a device that separates each CLEC's traffic out from the commingled packets carried over the feeder facility and aggregates each CLEC's packets onto a facility that connects to the CLEC's data network.[20] This is the first centralized point at which the ILEC can deliver an individual CLEC's data traffic to the competitor.

C. The ILECs' Next Generation Architecture Holds the Potential for Great Consumer Benefits but Also the Danger of Great Competitive Harms.

36. Increasing the use of fiber and placing the electronics closer to retail subscribers has made it possible to increase and improve the transmission capacity of loops for all customers,

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weighs about 5.7 pounds per foot. Depending upon whether the area is urban, suburban, or rural, copper cable may require splice points every 300 to 1,000 feet. Fiber, on the other hand, weighs only 0.13 pounds per foot (for a cable containing 108-216 fiber strands), and may run for 20,000 feet between splice points. In addition, the FCC Synthesis Model indicates that 26 gauge (2400 pair) copper feeder costs $16.94 per foot while 24 strand fiber costs only $1.79 per foot. Thus, the conductor cost for copper is roughly nine times the cost of fiber. While fiber incurs additional costs for central office electronics, those electronics permit much greater transmission capacity (by many orders of magnitude) than does copper.

[20] In circumstances where the CLEC opts to deliver the traffic to a remote location, the concentrated CLEC signal would be delivered to the interoffice network for subsequent delivery to a "Gateway" node or location.

but particularly for customers who are located at extended distances from the central office. Thus, the introduction of next-generation architecture permits ILECs and their data affiliates to provide a whole host of new services, and higher-quality existing services, to their customers.

37. For example, a major benefit of remote terminal deployment is that more consumers can obtain xDSL services. With the traditional all-copper loop, approximately 20 percent of all customers, and an even higher percentage of customers in rural areas, are located more than 18,000 feet from a central office, which is the current technical limit for access to most ADSL services. Where RTs are deployed to shorten copper subloops, these customers can be reached with xDSL offerings. In addition, as discussed below, noise and other signal impairments on copper facilities are exacerbated as loops increase in length. Thus, the potential bit rates/transmission speed on copper loops are inversely related to distance, so that ever-shorter runs of copper translate into ever-higher digital transmission speeds.

38. Moreover, emerging services that require very high transmission rates can be accommodated through the use of very high data rate ("VDSL") technology, but only when the copper segment is shorter than 4,500 feet. Thus, use of the new RT-based technology will be of enormous benefit in making bandwidth necessary to enable consumers to access audio streaming, video streaming, and perhaps soon even video-on-demand feasible and thereby encourage further investment.[21]

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[21] *See, e.g.*, U.S. West, *Choice TV & Online Service* (visited Oct. 5, 2000) <http://www.uswest.com/products/ video-internet/choice/documents/vdsl_facts.doc> (fact sheet discussing the use of "VDSL and 'fiber-to-the-neighborhood' technologies to offer fully integrated video and high-speed services to residential and business customers"). Qwest is already providing such services to 52,000 subscribers. *See id.*

39. Critically, the deployment of new plug-in electronics closer to retail subscribers also improves the ILECs' economies in their loop plant where monopoly economies of scale are already substantial. Remote terminal locations are selected such that the distance from the RT site to the end user is relatively short. The RT equipment effectively mimics the central office environment in that it provides a location to interconnect facilities and transmission equipment. Thus, from a technical perspective, some of the functionality formerly provided at the central office has been moved closer to the end user. This permits the offering of digital services that were heretofore precluded because of extended distance or analog design. Moreover, it is feasible to encode digital services in a manner that permits multiple services to exist on the same line. These electronics enable the ILECs to efficiently provide both voice and data services to a huge embedded base of voice customers over a single line.

40. Thus, if properly deployed and operated in a nondiscriminatory manner, next generation RT-focused architectures have the potential to create an open, efficient, and forward-looking loop architecture that benefits everyone -- consumers, CLECs and ILECs alike. As described below, however, because these additional loop functionalities are deployed closer to customers, it becomes extremely difficult -- both practically and economically -- for more than one carrier to deploy this technology remotely, except in limited situations.

41. The speed and manner in which ILECs implement technology improvements, particularly in the loop plant, will substantially affect whether competition is advanced or thwarted. If competitive LECs are not able to access loops provided through the use of next generation equipment, they will not be able to offer consumers the full range of benefits flowing from the new hybrid fiber/copper networks, and will be at a significant competitive disadvantage vis-a-vis the ILECs.

IV. IN A NEXT-GENERATION NETWORK, COMPETITORS MUST BE ABLE TO ACCESS THE ENTIRE LOOP IN ORDER TO UTILIZE THE FULL TRANSMISSION FUNCTIONALITY AVAILABLE.

42. None of the adjustments that are being made in loop technologies alter the basic characteristics of the unbundled loop element that the Commission has recognized and incorporated into its current unbundling rules. First, and foremost, the loop still remains the essential pathway between the subscriber's premises and the central office. Thus, whenever the ILEC used DLC and fiber feeder to augment its copper loop plant using universal digital loop carrier plant, the Commission – and even the ILECs – simply (and properly) assumed that the multiplexing associated with those capabilities was part of the loop functionality. The loop configuration for next generation architecture is no different: a copper pair from a customer's premises connects to a remote terminal; fiber provides a connection from the RT to the central office; and transmission electronics terminate, interface and manage the efficient use of the two transmission media.[22]

43. Second, the function of the loop between the customer's premises and the central office is straightforward: it is the transmission functionality necessary for retail customers to send and receive information between their location and the network of the service provider. Again, however, the transmission functionality taking place in next generation RT architecture is no different than that the transmission functionality that takes place in a more traditional DLC architecture.

44. Next generation RT architecture enables the ILEC to separate the voice and data traffic in the field and to create separate paths for aggregated voice and aggregated data traffic back to the rest of the ILEC's network. All of this is part of the "classic" loop function, *i.e.*, the

[22] *See* Frontera/Hill Decl. ¶¶ 20-21.

functionality necessary to convey traffic from a customer's premises back to a frame on a central office where it can be delivered to a competitor for switching and other network functions. The electronics introduced in the RT simply allows for the loop to be more fully utilized by performing transmission functions more efficiently for a wider range of telecommunications customers and services.

45. Clearly, the copper distribution subloop provides a transmission functionality that no one can reasonably contest. Similarly, as in other uses of DLC, the fiber feeder facilities running from the remote terminal to the central office cannot be considered anything other than a transmission functionality.

46. The transmission functionality of fiber feeder facilities is limited only by the electronics the ILEC has deployed, and there is no reason why competitive carriers should not be permitted maximum flexibility, within broad network engineering parameters that ILECs have not yet specified (but should be required to demonstrate), to request all technically feasible fiber feeder capabilities as part of an entire loop. This would include providing levels of throughput assurances even if the ILECs (or their affiliates) are not themselves currently using such capabilities.[23] For example, when ATM transmission techniques are employed in the feeder, requesting carriers should have the option of obtaining any technically feasible transmission media in any possible format, including ITU-T Quality of Service Classes A, B, C, and D; ATM Forum Quality of Service Classes 1, 2, 3, and 4; and the following service class categories:

[23] Such a requirement would be similar to the FCC's unbundling rule for local circuit switching, which requires ILECs to make available all vertical features that the switch is capable of providing, regardless of the particular vertical features that the incumbent offers to its retail customers. *See* 47 C.F.R. § 51.319(d)(1)(i).

available bit rate, constant bit rate, real time and non-real time variable bit rate, and unspecified bit rate PVCs.[24]

47. As a general proposition, in all but rural areas, adding electronics to the fiber portion of the loop can be more cost efficient than adding more fiber. When one compares the cost of fiber deployment (the cost of cable and hardware termination), supporting structures (conduit, poles, and trenching), and labor (splicing, etc.) against the cost of installing multiplexing equipment of higher speeds at the RT and the central office (and the potential usefulness elsewhere of the low-speed multiplexer being replaced), the analysis frequently favors equipment upgrade. For example, if an ILEC installed fiber to the remote terminal with OC-3 capabilities, it would generally be cheaper to convert to OC-12 electronics than to install all new fiber. In addition, there are RT DLCs on the market today that permit in-place upgrades that increase the bandwidth capacity simply by replacing existing line cards with higher capacity line cards.[25]

48. The remotely deployed and "attached" electronics at an RT also provide traditional transmission functionality that is readily adaptable to the loop plant. Their purposes are to interoperate with central office equipment so as to maximize the efficiency of the feeder facility's transmission and, in some cases, to interoperate with customer premises electronics to

[24] A single circuit connecting two points and supporting a single service category is known as a virtual circuit. A permanent virtual circuit ("PVC") is one established via network management and is expected to be of long duration. If information is not being transmitted over the PVC, it does not take up space (bandwidth) on the network. However, a PVC is designed to be ready and waiting to receive cells whenever they are made by the subscriber.

[25] For older DLCs, upgrading capacity from OC-3 to OC-12 could require the installation of an additional common control assembly by plugging it into the old common control assembly.

increase the reach, efficiency and capability of the copper distribution facility's transmission.[26] These electronics are largely, if not exclusively, responsible for: (i) determining how much information a customer can transmit/receive per unit of time; (ii) controlling communications with the service provider's network; and (iii) determining the efficiency (and therefore the cost) of facility use. Finally, means to terminate and cross-connect facilities and equipment are provided at various secured points along the loop. In sum, RT loop electronics provide particularly critical transmission-related functionalities that determine the extent to which carriers can utilize the full potential of the loop.

49. As I explain in Part V. below, it is critical that multiple carriers have the ability to maximize the use of the electronics in an ILEC's RT, not merely an opportunity to deploy their own remote electronics, because in most instances, there is insufficient space to allow multiple carriers to deploy sufficient electronics remotely (*i.e.*, outside a central office collocation), and in virtually all cases it is economically infeasible to do so. As a result, competitors must rely on the equipment deployed by ILECs in order to access all of the capabilities of the UNE loop. In addition, an RT configuration enables the ILEC to achieve even greater economies of scale and scope than in the copper network architecture model, because the loop aggregation functions are performed even closer to customers than under standard DLC configurations. Thus, CLECs are even less likely to be able to replicate the RT architecture than they are to replicate the old copper loop plant model.

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26 As indicated in the Frontera/Hill Decl. at ¶¶ 21-22, loop electronics provide transmission and limited surveillance functionality.

50. In particular, the loop electronics that CLECs must be able to access include, but are not limited to, line cards and other remote terminal electronics, ILEC-owned line splitters, the statistical multiplexing functionality of ATMs and DSLAMs.

1. Line Cards and Other Remote Terminal Electronics -

51. A DLC system converts analog signals into digital signals, performs concentration functions, multiplexes multiple signals onto a single facility and may perform protocol conversion and buffering functions.[27] Whether or not a particular DLC configuration is designated "Next Generation," the functionality is essentially the same. The only significant differences relate to the efficiencies that can be achieved for the transmission media used.

52. The Commission has, from the outset, recognized that the DLC functionality, including the associated multiplexing and demultiplexing needed to get traffic on and off of high capacity facilities, is part of the loop element.[28] This is absolutely correct from a technical and engineering standpoint, because the principal reason for deploying DLC is to increase network efficiencies in the loop plant, not to perform conceptually different network functions. Next generation RT architectures are simply an even more efficient way of implementing the essential functionality of the loop.

53. Indeed, the functionalities provided by the DLC in a next generation architecture, including the plug-in, or "line card" used within the DLC, are transmission functions commonly employed in *any* transmission facility, regardless of whether loop or interoffice facilities are considered, including protocol conversion, buffering, modulation and multiplexing. This is not

[27] *See, e.g., Line Sharing Order*, ¶ 69, n.152.

[28] *Local Competition Order* ¶ 383.

only true from an engineering standpoint. All involve functions that the Commission has previously determined are subject to ILEC unbundling requirements, most particularly as regards the loop and associated electronics.[29] None of these functions can, or should, be considered "packet switching" functions.[30]

54. For example, some line cards may have circuitry that provides line splitting and DSLAM functionality on the same plug-in unit while other line cards do not. In all cases, however, the line cards are simply part of the loop, because they provide basic transmission functionality essential to structure the delivery of information to the loop transmission media so that the media's transmission capacity may be fully utilized.

55. In the *UNE Remand Order*, the Commission classified the DSLAM as part of the packet switching network element rather than the loop element.[31] As a technical matter, this is incorrect, especially as it relates to remotely deployed DSLAM capabilities in remote terminals. DSLAMs (as the name Digital Subscriber Line Access Multiplexer designates) provide *transmission*, not packet switching, functionality. The Commission has correctly found that

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[29] *See, e.g., Local Competition Order* ¶ 383; *UNE Remand Order* ¶ 175; *Advanced Services Memorandum Order* ¶ 54; *BA-NY 271 Order* ¶ 271.

[30] Even if the Commission should erroneously conclude that the line card contains some packet switching functions, that does not, or should not, mandate a finding that the line card should not be found to be "attached [loop] electronics." Such an exception would encourage ILECs to "hide" loops from competitors by placing the plug-in cards, and other critical electronics in their unregulated affiliates, where the ILECs would undoubtedly claim that they are beyond the reach of section 251(c).

[31] *UNE Remand Order* ¶ 303. AT&T has petitioned the Commission for reconsideration of its determination that DSLAMs are not included as part of the attached electronics within the definition of the loop. *See Implementation of the Local Competition Provisions of the Telecommunications Act of 1996*, CC Docket No. 96-98, AT&T Corp.'s Petition For Reconsideration and Clarification of the *Third Report and Order*, at 9-11 (filed Feb. 17, 2000).

packet switching involves the "routing [of] individual data units based on address or other routing information."[32] However, the DSLAM functionality included in the line card provides only a transmission functionality that permits more information to transit the loop (per unit of time) than would otherwise be possible.[33] The simple engineering fact is that the DSLAM makes *no* routing decision -- the key factor in the definition of a switch -- and indeed it cannot physically do so. One need only examine the current DSLAM technology to make this determination. In the remote terminal, a DSLAM has multiple subscriber loops on the customer side but only one or two facilities on the network side (depending on whether voice and data traffic are carried on the same, or separate fibers). Thus the DSLAM does not -- and cannot -- make any determination regarding the transmission path that will be used for a particular transfer of information.[34]

56. Thus, the remotely deployed DSLAM functionality in a line card performs multiplexing, concentration, protocol conversion and buffering functions -- all of which are transmission functions[35] -- but it does not perform switching. The DSLAM manages the information transfer from the customer premises and formats the transmission below 4 kHz into a GR303 format and formats the transmission in the higher frequencies into a cell (packet) format. Thus, protocol conversion, but no switching, occurs. The GR303 formatted signals are sent to one (and only one) circuit switch where switching occurs and the cell formatted

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32 *UNE Remand Order* ¶ 302.

33 It is conceivable that a packet switch could be deployed with only one connecting facility. In such a case, the switching aspect of the packet switch would effectively be dormant and the equipment would be providing solely a conductor optimization (*i.e.*, transmission) function.

34 Even in a central office environment, a DSLAM operates only as a multiplexer. A DSLAM has no ability to perform the basic function of a switch, i.e., to choose and establish real-time routing paths for particular communications.

35 Frontera/Hill Decl. ¶¶ 7-16.

transmission is sent to one (and only one) ATM device, which maps end users' cells to the initial data switch of various carriers' data networks.

2. *Statistical Multiplexing Functionality of ATMs*

57. ILECs' deployment of next generation network architecture to enhance the transmission functionality of the loop requires the addition of new equipment in the central office as well as in the remote terminals. For example, in order to concentrate and terminate data signals to various CLECs' networks, the ILECs must place an ATM-like piece of equipment in the central office.

58. As with many other kinds of telecommunications equipment, ATM-like equipment is multifunctional, serving two separate purposes. First, it manages the sending and receiving of signals over a facility (in this case the fiber-feeder portion of the network between the remote terminal and the central office), so as to maximize the use of that facility. Second (and separately), the ATM may perform the switching function of routing data packets throughout the ILEC's data network (only). Only the former functionality is associated with the loop element.

59. The DSLAM functionality in the line cards at the remote terminal encodes signals from multiple end users into an ATM format and places them in a commingled manner on a singled fiber conductor connecting to the ATM in the central office. Together, they perform what is called statistical multiplexing. Such multiplexing, unlike TDM, permits more information to be transmitted on a facility per unit of time because the arrangement does not require capacity to be reserved for end users that are not generating a signal. However, because cells of various carriers are commingled on a common feed facility, there must be some means to

place the cells on a facility that connects them to the carrier providing the data switching functionality. When it functions in this capacity, the ATM is providing only a demultiplexing/re-multiplexing function that simply puts all the cells destined for the same carrier on the same facility.

60. Indeed, in this capacity, the ATM functionality is no different than TDM, which is a clear transmission function that the Commission has recognized that the ILECs must provide in a UDLC configuration. With TDM, a CLEC customer's traffic is placed in a particular "time slot" and the CLEC is given access to that "time slot" in the central office. Similarly, with statistical multiplexing, the CLEC customer's traffic is put in packets and the CLEC is given access to that customer's packets only in the central office.

61. Access to the multiplexing functionality of the ATM is critical to CLECs' ability to serve their customers. Indeed, any other result would simply preclude CLECs from competing with the ILECs to provide the same services the ILEC (and its data affiliate) can offer. All CLECs require is a centralized place at which to collect their customers' voice and data signals, so they can connect the signals to a switch -- whether a circuit switch or a packet switch. CLECs have no objection if ILECs believe the most efficient place in their networks to aggregate data cells is at an ATM. However, from an engineering standpoint, this is the *true* end of the loop, *i.e.*, it is the first centralized point in the ILEC network where a CLEC can access its customers' communications.[36] Having chosen to gain the efficiencies of statistical multiplexing, however, ILECs cannot be heard to complain that they must provide CLECs with access to their

[36] Thus, even if there is another way to get at the customer's data "bits" at a central office collocation when the ILEC uses a standard copper loop to provide service (possibly supporting the limited access to DSLAMs in such cases), that is certainly not the case in the next-generation RT architecture.

customers' data cells at the ATM. Moreover, by allowing CLECs to access this limited functionality of the ATM, the CLECs do not benefit from any "switching" function that the ATM may also be capable of performing in other configurations. CLECs would specifically *not* be able to access the ATM's ability to perform facility integration that allow customers' cells (or packets) to reach their end point destination. Thus, the CLECs cannot use the ATM to provide an advanced service, and they have every economic incentive to invest in their own packet switching facilities to do so.

62. It is also impossible for CLECs to efficiently duplicate the ILECs' remote configurations. An ILEC can deploy the ATM functionality once in an office to support all the remote terminals homing on the central office and all CLECs interconnecting at the office. The only alternative available to CLECs, however would be for *each* CLEC in a central office to establish its own high capacity facility to *each* RT where its customers' copper subloops are terminated. This is extremely costly and wasteful of transmission capacity. No individual carrier could justify building its own facility at each RT where it might ultimately serve a customer.[37]

3. ILEC-owned Splitters -

63. The splitter is properly considered part of the loop because it plainly constitutes "attached electronics" necessary to provide CLECs the ability to take advantage of the full functions, features, and capabilities of the loop. A splitter is an electronic device that -- like the loop itself -- is necessary to enable a carrier to provide both voice and data services on the same

[37] Some of this waste might possibly be reduced if each carrier could deploy additional equipment at each remote terminal to perform an add/drop function and to interface with the DLC to permit use of a SONET ring architecture. However, as shown elsewhere in my declaration, there is typically no space for such equipment at an RT.